The Origins of British Nuclear Culture, 1895–1939

Kirk Willis

The images are familiar and ineradicable: cities scorched by blasts of tremendous heat, with thousands of civilians vaporized, thousands of others burned and disfigured, landscapes rendered desolate and uninhabitable by radiation; submarines, automobiles, luxury liners, and airplanes powered by clumps of uranium the size of a human fist; homes heated and cooled by limitless supplies of cheap energy drawn from secure reactors; land-based particle beam weapons capable of destroying airborne missiles and thus of providing a protective shield for civilian populations; eccentric physicists with thick central European accents, unkempt hair, ill-fitting clothes, and a crazed gleam of unearthly mischief in their eyes; politicians, civil servants, joint chiefs blinkered by hatred and ambition, ignorant of even the first principles of science and technology, careless of civilians, reckless in brinksmanship, and arrogant in assessments of military capability.

Such images, indeed, are part of the consciousness of all citizens of the atomic age: we who have stared at the newsreels of Nagasaki and Chernobyl, sat riveted with John Hersey's unforgettable *Hiroshima,*[1] laughed over the absurdities of *Dr. Strangelove* (1964), winced at the smiling publicity of atomic energy authorities or the local power company's plans for a new reactor, trembled at the apprarently inexorable proliferation of nuclear technologies into the Third and Fourth Worlds, or grown angry at the exaggerations—both budgetary and practical—of yet the latest "generation" of weapons systems. And yet the images of obliterated cities, atomic-powered ships, and particle beam weapons—images which have come to define so much of the

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[1] John Hersey, *Hiroshima* (New York, 1946).

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anxiety as well as opportunity of the postwar world—all existed in the popular consciousness in Britain and America long before August 1945, before, indeed, December 1941 or even September 1939. Nuclear culture—the knowledge, imagery, and artifacts of applied nuclear physics—long antedated August 6 and 9, 1945.

That prewar nuclear culture—like the nuclear science which ultimately underlay it—was of course in some measure international, the cumulative product of a wide array of sources ranging from plays, films, serials, comic books, novels, and science fiction tales to scholarly monographs, learned articles, and scientific popularizations which were freely translated, frequently subtitled, and thus widely disseminated. Nonetheless, there were—and, of course, still are—remarkable national differences within that culture—differences which have proven to a large degree determinant of postwar nuclear cultures and national policies—as over nuclear weapons development and atomic energy production. Such national cultures have, however, received only the most cursory study. Indeed, the exploration of American nuclear culture has begun only in the last half dozen years, although that scholarly effort has already produced a number of fascinating studies.[2] British nuclear culture, by contrast, has been almost entirely neglected. To be sure, British nuclear weapons development, British involvement in the making of the atomic bomb, British foreign and defense policies in the nuclear age, and the opposition within Britain to atomic weapons and nuclear technology have been much studied.[3] But the cultural history of nuclear science in Brtitain—the history of popular images of and attitudes toward nuclear power, atomic energy,

[2] Paul Boyer, *By the Bomb's Early Light: American Thought and Culture at the Dawn of the Atomic Age* (New York, 1985); H. Bruce Franklin, *War Stars: The Superweapon and the American Imagination* (New York, 1989); Peter Goin, *Nuclear Landscapes* (Baltimore, 1991); Spencer Weart, *Nuclear Fear: A History of Images* (Cambridge, Mass., 1988); Stephen J. Whitfield, *The Culture of the Cold War* (Baltimore, 1991).

[3] This literature daily grows more extensive. Among the most useful studies are Timothy J. Botti, *The Long Wait: Forging of the Anglo-American Nuclear Alliance, 1945–1952* (New York, 1987); Ian Clark and Nicholas J. Wheeler, *The British Origins of Nuclear Strategy, 1945–1955* (Oxford, 1989); Margaret Gowing, *Britain and Atomic Energy, 1939–1945* (London, 1964), and *Independence and Deterrence: Britain and Atomic Energy,* 2 vols. (London, 1974); A. J. R. Groom, *British Thinking about Nuclear Weapons* (London, 1974); Martin S. Navias, *Nuclear Weapons and British Strategic Planning, 1955–1958* (Oxford, 1991); Andrew J. Pierre, *Nuclear Politics: The British Experience with an Independent Strategic Force, 1939–1970* (London, 1972); Roger Ruston, *A Say in the End of the World: Morals and British Nuclear Weapons Policy, 1941–1987* (Oxford, 1989); Ferenc Morton Szasz, *British Scientists and the Manhattan Project: The Los Alamos Years* (New York, 1992); Richard Taylor, *Against the Bomb: The British Peace Movement, 1958–1965* (Oxford, 1988).

and nuclear weapons development—is all but unknown. And this omission is all the more regrettable given both the striking differences between American and British nuclear cultures and the direct effect popular attitudes have had on the growth and success of pressure groups and mass movements within Britain ranging from the Campaign for Nuclear Disarmament and Committee of 100 to the Atoms for Peace League and Institute for Atomic Information

I

Nuclear culture is, of course, a product of nuclear physics, and modern nuclear physics—or, more accurately, modern atomic physics—began at the very end of the nineteenth century with the discoveries, in 1895 and 1896, by Wilhelm Conrad Röntgen and Antoine Henri Becquerel of X-rays and radioactivity, and, at the turn of the century, with the pioneering work of Marie Curie and Pierre Curie on radium and Ernest Rutherford and Frederick Soddy on radioactive transmutation. Such discoveries revolutionized the study—and imagery—of physics and chemistry and sparked off their own chain reaction of research and further discovery which continues uninterruptedly. In the years from 1895 to 1939, the pace of change was positively dizzying—for participants as well as observers—as physicists and lay audiences learned a new language of X-rays, alpha particles, electrons, neutrons, half-lives, relativity, quantum mechanics, cyclotrons, positrons, plutonium, fission, fusion, and on and on and on.[4]

Crucially for the development of British nuclear culture, much of that pioneering work was done by British subjects—by J. J. Thomson and Rutherford, by Soddy and James Chadwick, by Harry Moseley and William Ramsay, by Patrick Blackett and John Cockcroft, by P. A. M. Dirac and Francis Aston, to name but the most distinguished. Furthermore, most of their work was done in Britain itself—especially at the Cavendish Laboratory at Cambridge, which (until the coming of the Second World War) was incomparably the leading center of research in experimental physics in the world, its only rivals being the Curies' lab in Paris and Ernest Lawrence's fledgling Radiation Laboratory at Berkeley. Virtually all that work was of a spectacularly—and increasingly—technical nature, heavily reliant on mathematics and made even more so by the introduction of relativity and

[4] Good introductions to the evolution of atomic and nuclear physics can be found in Alex Keller, *The Infancy of Atomic Physics: Hercules in His Cradle* (Oxford, 1983); and Abraham Pais, *Inward Bound: Of Matter and Forces in the Physical World* (New York, 1986).

quantum theory in the 1910s and 1920s. Unmediated physics thus became wholly unintelligible to the lay audience and was buried in specialist journals read exclusively by the initiated.

The British press and scientific community therefore found themselves challenged as never before to explain the new discoveries to a lay readership—an audience keen to learn of X-rays, radioactivity, and the like and eager to celebrate Britain's national scientific achievements. Beginning in the first two decades of the new century, but with a quickening pace in the interwar years, the number of scientifically trained journalists—such as J. W. N. Sullivan and J. G. Crowther—expanded rapidly, as did the ranks of journalism-minded scientists, most notably A. S. Russell, Oliver Lodge, W. C. Dampier Whetham, Arthur Eddington, Ray Lankester, and Rutherford himself. Both groups reported on recent discoveries and their implications, not merely in the leading newspapers, but more prominently (and fully) in the major reviews—the *Quarterly, Fortnightly, Contemporary, Nineteenth Century, Westminster,* and *Edinburgh*—reviews which may have lost some of their mid-Victorian grandeur but which still reached a wide audience. Many of these journalists and scientists, moreover, contributed regularly to the growing number of publications of popular science, most importantly *Science Work* (established 1898), *Science Progress* (1906), *School Science Review* (1919), and preeminently, *Discovery* (1920). These same writers, furthermore, also published avowedly popular introductions to the new physics, books such as Bertrand Russell's immensely successful *The ABC of Atoms* (1923) and *The ABC of Relativity* (1925), E. N. da C. Andrade's *The Atom* (1927), J. W. N. Sullivan's *Atoms and Electrons* (1923), Oliver Lodge's *Atoms and Rays* (1924), and G. K. T. Conn's *The Nature of the Atom* (1939), books which ran through many editions and reprintings and which continued to appear in growing numbers right up to the outbreak of war in September 1939.[5]

This journalism was of course virtually contemporaneous with the science it sought to explain, and as early as March 1896 articles on the work of Röntgen and Becquerel began to appear in the British press.[6] Indeed, the discovery of X-rays provoked the same popular

[5] Bertrand Russell, *The ABC of Atoms* (London, 1923), and *The ABC of Relativity* (London, 1925); E. N. da C. Andrade, *The Atom* (London, 1927); J. W. N. Sullivan, *Atoms and Electrons* (London, 1923); Oliver Lodge, *Atoms and Rays* (London, 1924); and G. K. T. Conn, *The Nature of the Atom* (London, 1939).

[6] See, e.g., Peter Kropotkin, "Recent Science: Röntgen Rays," *Nineteenth Century* 39 (March 1896): 416–25; Agnes Mary Clerke, "The Photography of the Invisible," *Quarterly Review* 183 (April 1896): 496–507; David Walsh, *The Röntgen Rays in Medical Work* (London, 1897); Silvanus P. Thompson, *Light Visible and Invisible* (London, 1897); W. Awdry, *Early Chapters in Science* (London, 1899); William Ramsay, "The

enthusiasm in Britain in the last years of the nineteenth century as it did on the Continent and in North America. Not merely were public lecture halls packed with volunteers eager to have their hands and skulls X-rayed, but the therapeutic promises and commercial applications presented by X-rays were seized on by the journalistically sensational, the medically unscrupulous, and the physically desperate. So great was the fascination worldwide, indeed, that over one thousand books and articles on X-rays appeared in 1896 alone; in the words of Lawrence Badash, "Not until the public announcement of an atomic bomb in 1945 would a scientific achievement receive greater attention in the newspapers and magazines."[7]

The discovery of radium and of radioactive transmutation in the first years of the new century ignited a similar explosion of public interest. The diagnostic and therapeutic properties—both real and imagined—of radium were proclaimed without restraint and beyond credibility. "Radium dances in ballets . . . radium collars, radium stoves, and radium polish" appeared, as did countless patent medicines, nostrums, and trinkets.[8] By 1905, to quote Badash again, "Scarcely a person in the civilized world was unfamiliar with the word 'radium' or the name of its discoverer."[9] Even if not always well schooled in the scientific niceties, the British reading public was nonetheless at least aware of the ongoing revolution in physics and responsive to both accounts of its development and speculations as to its implications.

In Britain itself special attention was paid not simply to the potential medical applications of radium and X-rays but also to the discovery, in 1901–2, of radioactive transmutation by Ernest Rutherford and Soddy. Much of the credit for that unusual attention rested with the deliberately provocative and flamboyant popular writings of Soddy himself, writings which swung wildly from the millennial to the apocalyptic, the austere to the rhapsodic. A brilliant if querulous chemist who collaborated with Rutherford in Montreal and with Ramsay in London and who would later be Dr. Lee's Professor of Chemistry at Oxford and a Nobel laureate, Soddy possessed a fertile imagination, a lively prose style, and a relentless determination to proclaim what he judged to be the implications of the new discoveries in physics and

Becquerel Rays," *Contemporary Review* 81 (May 1902): 730–40; Peter Kropotkin, "Recent Science: Unsuspected Radiation," *Nineteenth Century* 48 (December 1900): 919–33.

[7] Lawrence Badash, *Radioactivity in America: Growth and Decay of a Science* (Baltimore, 1979), pp. 9, 11.

[8] Illustrated in William Hampson, *Radium Explained* (London, 1905), p. 1.

[9] Badash, *Radioactivity*, pp. 24–25.

chemistry to the general public. To that end he was an indefatigable lecturer and essayist, never refusing a chance to speak of his findings or refusing an opportunity to tell a new audience of the both wondrous and dangerous implications of those discoveries.

Typical of these popular writings was a superb essay which appeared in the May 1903 issue of the *Contemporary Review:* "Some Recent Advances in Radioactivity: An Account of the Researches of Professor Rutherford and His Co-workers at McGill University."[10] Largely what its title promised—a brief progress report on Rutherford's (and Soddy's own) pathbreaking work on radioactivity—the article concluded with a characteristically striking speculation concerning a new term which Soddy helped to popularize and, with Rutherford, to coin: "atomic energy." One of the as yet least appreciated but most important implications of the discovery of radioactive disintegration, Soddy explained, was the existence of the "truly colossal" force of energy which normally binds atoms together, a force thus far unmeasured but one which "must represent an amount of energy in the universe hitherto undreamt of." To be sure, he was quick to concede, physicists and chemists had as yet no idea what "controls these gigantic forces" or "whether it will ever be found possible to draw upon them for the world's work." Nonetheless, he observed, the general public as well as the scientific community could only be heartened by the discovery of "quantities of energy vastly greater than any that have been before suspected."[11]

There was, however, a darker side to these speculations, one which Soddy presented in a dramatic image. Knowledge of the mere existence of atomic energy, he observed ominously, must "alter our attitude towards inanimate matter, and make us regard the planet on which we live rather as a storehouse stuffed with explosives, inconceivably more powerful than any we know of, and possibly only awaiting a suitable detonator to cause the earth to revert to chaos."[12] At the moment, neither Rutherford, Curie, nor Soddy himself could predict the future course or pace of research, Soddy explained. Nor could anyone even explain the source or true nature of "atomic energy." Nonetheless, the stakes were high, and the issues genuinely "cosmical in their scope and character": in a matter of a few years, Soddy was confident, science would be in a position both to master

[10] Frederick Soddy, "Some Recent Advances in Radioactivity: An Account of the Researches of Professor Rutherford and His Co-workers at McGill University," *Contemporary Review* 83 (May 1903): 708–20.

[11] Ibid., pp. 718, 720.

[12] Ibid., p. 720.

and to unleash atomic energy, with consequences at once elysian and infernal.[13]

Such was the essentially buoyant nature of Soddy's temperament, however, that when he returned to the task six weeks later in two lively essays in *The Times Literary Supplement* (*TLS*), he was far more cheerful and optimistic. Entitled "The Disintegration Theory of Radioactivity" and "Possible Future Applications of Radium," these articles sought at once to pander to what Soddy judged to be the "national characteristic, not to say national failing" of the British always "to be preoccupied with the 'practical use' " of radioactivity and to scold British industry for lagging behind their continental brethren in the production of radium and radium products.[14] Although "the potentialities of discovery are so obvious that the eternal question of utility may be said to answer itself," Soddy explained, he nonetheless went on to list the most obvious and immediate: "in the treatment of cancer," "for illuminating purposes," and "for the ordinary work of the industrial world." So enthusiastic was Soddy about the imminent liberation and control of atomic energy, indeed, that he offered the absurdly sanguine observation that only "a single step in science is needed" in order to guarantee an abundance of cheap energy "in a manner beyond the dreams even of the scientific novelist."[15] And by way of illustration, Soddy—a master of such arresting images—offered two examples of the astonishing potential of atomic energy: "The energy stored up in one gram of radium is sufficient to raise 500 tons a mile high. An ounce would therefore suffice to drive a 50-h. p. motor car at the rate of 30 miles an hour round the world."[16]

The next year—1904—saw Soddy's optimism blossom even more lavishly. Not only did he lecture on the potential beneficence of atomic energy to groups as diverse as the Corps of Royal Engineers at the School of Military Engineering and the Manchester Literary and Philosophical Society, but he also published a popular introduction to contemporary physics, *Radio-Activity: An Elementary Treatise,* which emphasized the enormous energy "bound up and latent in the structure of the atom."[17] Moreover, while on a long journey by steamship to the Antipodes, he made a memorable calculation which he proclaimed

[13] Ibid.

[14] [Frederick Soddy], "The Disintegration Theory of Radioactivity," *TLS* (June 26, 1903), p. 201.

[15] [Frederick Soddy], "Possible Future Applications of Radium," *TLS* (July 17, 1903), p. 226.

[16] Ibid.

[17] Frederick Soddy, *Radio-Activity: An Elementary Treatise* (London, 1904), p. 34.

at every opportunity both in Australia and (on his return) in Britain: a pint bottle of uranium contained enough energy to drive an ocean liner from London to Sydney and back. Indeed, he asserted in another magazine article, if scientists could but take that "single step" and learn to tap the energy within atoms, "the future would bear as little relation to the past as the life of a dragonfly does to that of its aquatic prototype."[18] Four years later Soddy surpassed himself, and in the peroration to his most widely read book, *The Interpretation of Radium* (1908), prophesied, "A race which could transmute matter would have little need to earn its bread by the sweat of its brow. . . . Such a race could transform a desert continent, thaw the frozen poles, and make the whole world one smiling Garden of Eden."[19]

However compelling or hyperbolic such visions of prelapsarian bliss may have seemed to contemporaries, they also perplexed Soddy's audiences (as well as enraged nearly all of his more cautious scientific colleagues who well knew how far Soddy was racing before his or anyone else's evidence). Bewilderment stemmed in part from Soddy's repeated—and equally vivid—references to "storehouses stuffed with explosives" and "weapons by which to destroy the earth."[20] For all his constitutional optimism, that is, Soddy was simply too good and too honest a scientist to ignore the ominous potentialities of atomic energy, however far into the distance those potentialities might be. And although his many readers and listeners were doubtless struck by the essential sunniness of his future, some—as will be seen—paused to meditate about the darker aspects of atomic energy.

Such meditations—and such perplexities concerning the ambiguous promise of atomic energy—were made the more uncertain and nettlesome by both the speculative character of all of Soddy's predictions and the cautious nature of contemporary scientists. Soddy, after all, was writing in the very midst of a revolution in physics and chemistry; his essays in the *Contemporary Review* and *TLS* appeared only months after his and Rutherford's earliest papers and simultaneously with his work with Ramsay. His excitable temperament and dedication

[18] Quoted in Weart (n. 2 above), p. 6.

[19] Frederick Soddy, *The Interpretation of Radium* (London, 1908), p. 244.

[20] In his lectures to the Royal Engineers, Soddy had remarked, "It is possible that all heavy matter possesses latent and bound up with structure of the atom, a similar quantity of energy to that possessed by radium. If it could be tapped and controlled what an agent it would be in shaping the world's destiny! The man who put his hand on the lever by which a parsimonious nature regulates so jealously the output of this store of energy, would possess a weapon by which he could destroy the earth if he chose." Quoted in Muriel Howorth, *Pioneer Research on the Atom: The Life Story of Frederick Soddy* (London, 1958), p. 123.

to the popularization of science, however, led him almost irresistibly, if not recklessly, into fanciful images, popular language, and premature conclusions.

By comparison, virtually all of his scientific colleagues were positively staid. Rutherford, for example, preferred in these early years to write exclusively for a professional audience; there was a world of difference, for example, between his textbook, *Radio-Activity* (1904) and Soddy's similarly titled and simultaneous survey. Published in the Cambridge University Press's distinguished Cambridge Physical Series, Rutherford's book is careful, sober, and uncompromisingly "academic"; its wildest statement concerning atomic energy, indeed, was the cautious recognition that "there is thus reason to believe that an enormous store of latent energy is resident within atoms."[21] Similarly, the distinguished physicist R. J. Strutt, later Lord Rayleigh and professor of physics at Imperial College, was prepared in his own early book on radium only to acknowledge that "there lies latent in the atom a quantity of energy absolutely gigantic in comparison with anything which it was formerly believed to contain." As to the prospect of releasing and harnessing that latent energy, Strutt offered only the most tepid assessments and in the most guarded of language. "It is not inconceivable," he concluded weakly, "that some process might be discovered which would enable us to liberate such stores of energy on a large scale."[22] The distinguished Birmingham physicist Lodge, by contrast, offered only the coldest of water in response to speculations such as Soddy's. In his Romanes Lecture on "Modern Views on Matter" delivered in Oxford in June 1903, Lodge warned against "popular and gratuitous surmise" and "irresponsible speculation," charges he repeated in an essay on "Radium and Its Lessons," published in the *Nineteenth Century* the next month: "Let me conclude by asking readers to give no ear to the absurd claim of paradoxers and others ignorant of the principles of physics, who, with misplaced ingenuity, will be sure to urge that the foundations of science are being uprooted and long-cherished laws shaken. Nothing of the kind is happening."[23] And to perplex lay readers still further, the respected Cambridge scientist and popular science writer W. C. Dampier Whetham paused at the end of a long and lucid essay on "Matter

[21] Ernest Rutherford, *Radio-Activity* (Cambridge, 1904), p. 337.

[22] R. J. Strutt, *The Becquerel Rays and the Properties of Radium* (London, 1904), pp. 138–39.

[23] Oliver Lodge, "Modern Views on Matter," reprinted in the *Annual Report of the Smithsonian Institution* (Washington, D.C., 1904), p. 226, and "Radium and Its Lessons," *Nineteenth Century* 54 (July 1903): 85.

and Electricity" in the April 1904 *Quarterly Review* to repeat one of Rutherford's rare and characteristically private conjectures: "Professor Rutherford has playfully suggested to the writer the disquieting idea that, could a proper detonator be discovered, an explosive wave of atomic disintegration might be started through all matter which would transmute the whole mass of the globe into helium of similar mass, and, in very truth, leave not one stone upon another."[24]

In the face of such wildly divergent opinions from some of Britain's more distinguished scientists, lay readers could have been forgiven their confusion and alarm. That "science is trembling on the verge of something," seemed indisputable; that "a vast reservoir of atomic energy" had been discovered seemed equally plain; but whether that reservoir—if ever tapped—would lead to a smiling Garden of Eden, to an atomic catastrophe, or to neither seemed not merely unclear but indeterminable.[25] What was needed, and what in the event occurred, was an immense effort of basic scientific research along a broad range of physical and chemical fronts. The next ten years thus saw many fewer articles in the popular press but an explosion of literature in the technical journals.[26] Lay readers did not of course forget what they had learned, and some few scientists—most especially Soddy—proved incorrigible, but in the decade from 1905 until the outbreak of the First World War—years of astonishing and unparalleled advance in physics in Britain, America, and the Continent—there was a relative paucity of popular works on atomic physics. What few works there were, moreover, tended to cluster into three categories. The first and largest group focused on the therapeutic effects of radium and X-rays on a growing range of ailments. Louis Wickham and Paul Degrais's *Radium Therapy* (1910), J. G. Speed's "The Brain, X-Rays, and the Cinematograph" (1911), and G. W. C. Kaye's *X-Rays* (1914)

[24] W. C. D. Whetham, "Matter and Electricity," *Quarterly Review* 183 (April 1904): 126. Whetham repeated the speculation in his enormously popular textbook, *The Recent Development of Physical Science* (London, 1904), where he dismissed it as "only a nightmare dream of the scientific imagination" (p. 245). Whetham, himself an important scientist and colleague of Rutherford's at Trinity College, asked and received Rutherford's permission to include the potentially alarmist passage. What Rutherford had in fact said was, if anything, even more frightening: "Some fool in a laboratory might blow up the universe unawares" by setting off an uncontrolled "wave of atomic disintegration through matter." Quoted in A. S. Eve, *Rutherford* (Cambridge, 1939), p. 102.

[25] Antonia Zimmern, "The New Discoveries in Electricity," *Nineteenth Century* 55 (January 1904): 89; "The Revelations of Radium," *Edinburgh Review* 198 (October 1903): 398.

[26] An excellent account of this research can be found in Keller (n. 4 above), pp. 98–146.

were characteristic texts, lucid and careful not to promise too much.[27] The second cluster of work consisted of progress reports concerning ongoing research into radioactivity, the structure of the nucleus, and the like. Often quite technical, such as Rutherford's, *Radioactive Transformations* (1906), Walter Makower's *Radioactive Substances* (1908), and Whetham's "The Individual Atom" (1913), these works were usually detailed accounts of experimental work and addressed largely to specialist audiences.[28] The third and smallest group were avowedly popular surveys aimed at a broad lay audience. Easily the most successful of this group was John Cox's *Beyond the Atom* (1913), although Soddy's *Matter and Energy* (1912) and Arthur Schuster's *The Progress of Physics, 1875–1908* (1911) also found wide readerships.[29] Cox, an important physicist who was director of the Macdonald Laboratory at McGill during Rutherford's tenure there and then preceded Rutherford back to Trinity College, Cambridge, enjoyed a fluent pen, a mastery of the scholarly literature, and a capacity to write clearly for the intelligent lay reader. He also shared Rutherford's caution concerning the possible "practical applications" of current research, especially in regards to the "unsuspected and enormous stores of atomic energy [which] have been brought into view." Although the prospect of "the unlocking of vast stores of atomic energy" is an attractive one, Cox confessed, he warned that scientists—both now and in any foreseeable future—are "impotent to delay or hasten" atomic change.[30] The many readers of Cox's book thus came away with a great admiration for both the experimental virtuosity and the theoretical cleverness of men such as Rutherford, Thomson, Ramsay, and Soddy, but with little hope that their discoveries would soon yield any practical fruit.

[27] Louis Wickham and Paul Degrais, *Radium Therapy,* trans. S. Ernest Dove (London, 1910), *Radium as Employed in the Treatment of Cancer,* trans. A. Bateman and A. C. Bateman (London, 1911), and "Radium: Its Use in Cancer and Other Diseases," *Contemporary Review* 98 (August 1910): 174–88; J. G. Speed, "The Brain, X-Rays, and the Cinematograph," *Westminster Review* 175 (March 1911): 269–73; G. W. C. Kaye, *X-Rays: An Introduction to the Study of Röntgen Rays: Their Properties and Behaviour* (London, 1914). See also David Walsh, *The Röntgen Rays in Medical Work,* 4th ed. (London, 1907); and E. E. Fournier, *The Wonders of Physical Science* (London, 1910), pp, 178–90.

[28] Ernest Rutherford, *Radioactive Transformations,* 2d ed. (New Haven, Conn., 1908); Walter Makower, *The Radioactive Substances* (London, 1908); W. C. D. Whetham, "The Individual Atom,"*Quarterly Review* 219 (July 1913): 104–24.

[29] John Cox, *Beyond the Atom* (Cambridge, 1913); Frederick Soddy, *Matter and Energy* (London, 1912); Arthur Schuster, *The Progress of Physics, 1875–1908* (Cambridge, 1911).

[30] Cox, pp. 145–46.

Distinguished scientists and their popularizers were not, however, the only sources of knowledge concerning the potential effects—both baleful and beneficial—of the new discoveries in physics and chemistry. Novelists, short story writers, and even comic strip artists also allowed their imaginations to roam freely and created visions far more expansive than those offered by scientists. As early as 1895—the very year of Röntgen's earliest discoveries—the Irish journalist and adventure novelist Robert Cromie seized on the notion of atomic decomposition implied in Röntgen's work and placed it at the heart of a new novel, *The Crack of Doom*. A dismally written and absurdly contrived tale which nonetheless attracted a wide readership, the novel features a group of stereotypically fiendish scientists and "rational thinkers" whose leader invents a device capable of initiating atomic disintegration and thus (through the "wreckage of its constituent atoms") earthly oblivion.[31] The device, "encased in a hollow glass ball the size of a pea," holds within it a single drop of water. When touched by an unspecified "chemical agent," "the atoms of the water [are] resolved into the ultimate ether of which they were composed" and set off a fierce reaction culminating in the destruction of the earth.[32] The dastardly plans of the chief villain thus to "etherise" the planet are thwarted in the end by the protagonist, who alters the formula of the agent and causes not the atomic decomposition of the globe but rather a massive earthquake which destroys the Malaysian island from which the ultimate destruction was to proceed.

Fourteen years later an English translation of Anatole France's allegorical novel *Penguin Island* similarly drew on atomic images of destructiveness. In France's more skillfully crafted novel, a tiny group of chemically adept "dynamitards" employ small, yet immensely destructive explosives shaped like "an egg made of white metal and provided with a capsule at each end." Such pocket-sized devices, which are never called atomic bombs, draw their force "from a gas which radium evokes."[33] Similar, and equally vague, uses of the power of radioactivity appeared as well in George Griffith's *The Lord of Labour* (1911)—another dreary novel in which German physicists invent a radium-based ray capable of disintegrating metal, and British scientists retaliate with radium-helium bullets—and in the comic strip "Puck," in which a "Professor Radium" thwarts evildoers of endless varieties.[34]

[31] Robert Cromie, *The Crack of Doom* (London, 1895), p. 18.
[32] Ibid., pp. 106, 108–9.
[33] Anatole France, *Penguin Island,* trans. A.W. Evans (London, 1909), p. 340.
[34] George Griffith, *The Lord of Labour* (London, 1911).

Although such limited uses of atomic imagery were rare in the years before the First World War, they reached a wide audience and cumulatively contributed to a growing popular conviction of the essentially threatening nature of contemporary atomic physics. This pessimism received dramatic, if in some ways unintended, new expression in the winter of 1913 when H. G. Wells began to serialize what he described as a "good old scientific romance," *The World Set Free,* in the *English Review*. Published in book form just weeks before the outbreak of the Great War, *The World Set Free* was dedicated to "Frederick Soddy's Interpretation of Radium" and was avowedly inspired by Soddy's popular writings as well as by his direct conversations with Wells concerning the potential implications of radioactive disintegration.[35] Not one of Wells's finest efforts, the novel is disjointed, ill-organized, and populated with caricatures rather than characters. The only feature which at once rescues it from complete obscurity and made the greatest impression on contemporaries is Wells's prophetic invention of Soddy's projected "detonator": an "atomic bomb." No reviewer failed to remark on the new device, and no later commentator can avoid pausing to praise Wells's prescience.[36] Wells himself, however, sought not merely to devise a new superweapon but also to develop a much larger theme—again owed explicity to Soddy—about the possibilities, both glorious and pernicious, of atomic energy. Indeed, the initial title of the book, "The Atom Liberates the World," conveys the point Wells wished to develop. Unfortunately, the mediocre quality of the book, the almost simultaneous outbreak of the war, and the eventual creation of atomic weapons have all combined to obscure Wells's original purpose and to focus attention almost exclusively on the invention and use of the bomb. To contemporaries, however, ignorant not merely of Hiroshima but also of Sarajevo, it was the ambiguous nature of the "freedom" promised by atomic energy as much as the cataclysm of atomic warfare which struck their imaginations and reinforced earlier, frightening images of atomic physics drawn from Soddy, Cromie, Whetham, Griffith, and others.

[35] "I've suddenly broken out into one of the good old scientific romances again," Wells informed his old friend, A. T. Simmons, "and I want to know quite the latest about the atomic theory and sources of energy. I've read and mastered Soddy's very good little book and I want more. My idea is taken from Soddy. Men are supposed to find out how to set up atomic degeneration in the heavy elements just as they found out long ago how to set up burning in coal. Hence limitless energy." Quoted in Geoffrey West, *H. G. Wells: A Sketch for a Portrait* (London, 1930), p. 199; see H. G. Wells, *The World Set Free* (New York, 1914).

[36] See, e.g., reviews in *TLS* (May 14, 1914), p. 238; *Nation* 15 (May 9, 1914): 218; *Saturday Review* (May 9, 1914), pp. 605–6.

The novel—set variously in the 1930s, 1950s, and 1970s—opens with a clear indication of its major theme: "The history of mankind is the history of the attainment of external power."[37] Much of the long introductory chapter is therefore full of characteristically Wellsian anthropological and historical speculation confidently parading as social science. The central thrust is plain enough, however: throughout all human history progress has been dependent on the mastery of a succession of "external" sources of energy, from animals to water to steam to coal. In 1933, the reader learns in the first full chapter, a young scientist working alone in digs in Bloomsbury discovered—"by a wonderful combination of induction, intuition and luck"—artificial radioactivity as a consequence of experiments with bismuth.[38] Soon, though a series of necessarily ill-described experiments, the young researcher succeeded in tapping the practically infinite stores of atomic energy. Within twenty years industrial applications had become complete: atomic engines powered trains, trams, ships, automobiles, and airplanes; atomic motors drove virtually every form of industrial equipment from conveyor belts to mining pumps to household appliances; and atomic waste proved to be not dangerous radioactive uranium but, pure, plain, and abundant gold.

Unfortunately, such applications produced as much misery as joy and caused the same sort of social dislocation as had the introduction of steam power a century and a half earlier. Not merely did the new technology force "millions of coal-miners, steel-workers upon the old lines [and] vast swarms of unskilled or under-skilled labourers in innumerable occupations" to be "flung out of employment by the superior efficiency of the new machinery," but the "rapid fall in the cost of transport destroyed land-values at every centre of population, [and] made the value of existing house property problematical." Furthermore, the sudden abundance of gold prompted "headlong depreciation [with] all the securities upon whch the credit of the world rested slipping and sliding, the banks tottering, [and] the stock exchanges scenes of feverish panic."[39]

Worse yet, the colossal power of atomic energy was also harnessed to weapons of war, and when a European- (and then world-) wide war began in 1956 as a consequence of a German invasion of the Low Countries, the new, plentiful, and cheap atomic bombs were used on every side. Most ominously, these atomic bombs exploded not once

[37] Wells, *The World Set Free,* p. 1.

[38] Ibid., p. 40. Wells missed his prediction of the discovery of artificial radioactivity by but one year; 1934 would see the Joliot-Curies' discovery.

[39] Ibid., pp. 55, 79.

but continuously, rather like a volcano in near-constant eruption or a modern reactor in full meltdown.[40] Their impact was therefore if anything even more destructive, for they rendered the major cities of the belligerents—and soon the chief cities of the world—permanently uninhabitable. A visitor to Paris, for example,

> would have entered also a zone of uproar, a zone of perpetual thunderings, lit by a strange purplish-red light, and quivering and swaying with the incessant explosion of the radio-active substance. Whole blocks of buildings were alight and burning fiercely, and trembling ragged flames looking pale and ghastly and attenuated in comparison with the full-bodied crimson glare beyond.
>
> Every step further would have been as dangerous as a descent within the crater of an active volcano. These spinning, boiling bomb centres would shift or break unexpectedly into new regions, great fragments of earth or drain or masonry suddenly caught by a jet of disruptive force might come flying by the explorer's head, or the ground yawn a fiery grave beneath his feet. Few who adventured into these areas of destruction and survived attempted any repetition of their experiences. There are stories of puffs of luminous, radio-active vapour drifting sometimes scores of miles from the bomb centre and killing and scorching all they overtook.[41]

By the end of the war, the two hundred most important cities in the world had been reduced to sites of "the unquenchable crimson conflagrations of the atomic bomb."[42] Through a sort of natural compulsion, this near extinction of civilization taught the survivors a lesson and impelled them irresistibly to create a world government that nurtured an uncertain new society. At the story's end, citizens are traveling where they choose in atomic-powered "aircars," building atomic-powered garden cities in deserts and in arctic wastes, and enjoying unprecedented leisure and free love. And yet the new atomic technology had still rendered hundreds of thousands of workers obsolete; promised no hope of employment to many, if not most, of their children in this labor-saving age; made most of the earth's surface uninhabitable and all of civilization's previous treasures inaccessible in burning cities; destroyed the world economy through the proliferation of gold; and created a rational, orderly, technologically advanced society in which there is no joy, love, or humor. Wells thus produced at once a prescient atomic Armageddon and an ambiguous nuclear millennium.

[40] Ibid., p. 113.
[41] Ibid., p. 221.
[42] Ibid., p. 137.

By detailing in an unprecedented manner the manifold consequences of atomic energy, he managed to produce a vision which at once arrested and repelled contemporaries; tellingly, not a single reviewer found a kind word to say about the world Wells set free. For all his debt to Soddy, that is, Wells offered an atomic utopia that was no smiling Garden of Eden.

He did, however, create an unforgettable superweapon, and when the Great War burst into flame only weeks after the appearance of *The World Set Free,* Wells's account of a technology-driven war originating in the Low Countries seemed painfully prophetic. Four years of unprecedented destruction by ever more lethal and sophisticated weapons, moreover, only deepened the connection between scientific research and military application in the popular mind and turned public attention away from the distant prospects of an atomic bomb to the immediate realities of poison gas, aerial warfare, and civilian bombing. Military planners, strategic specialists, Foreign Office mandarins, political commentators, and popular novelists all worried over the revolution in mechanical warfare that had plainly and irresistibly been set in train by the war. A rich genre of "next-war fiction," for example, flourished in the 1920s and 1930s—novels, plays, and science fiction tales which, with but a few exceptions to be discussed later, focused on the immediate threat of air raids, poison gases, and "death rays" rather than on the potential menace of atomic weapons.[43]

Nor, in the years immediately after the close of the war, did scientific popularizers pause either to imitate or to extend Wells's speculations. Rather, they concentrated quite naturally and narrowly on the Herculean task at hand: to explain to a fascinated yet confused lay audience the astonishing revolution in physics that swept forward in the aftermath of the war. Quantum mechanics, relativity theory, nuclear structure, nuclear physics—the list was long, the issues complicated, the implications manifold, and it is perhaps not surprising that popular science writers—both scientists and journalists—contented themselves merely with presenting the latest findings.

In the months just after the war ended, relativity theory had pride of place in this effort at scientific popularization. Sheer astronomical chance was responsible for this preeminence, for on May 29, 1919, a solar eclipse offered the opportunity of validating Einstein's general theory of relativity. When a carefully planned observation of that

[43] The best studies of this literature are Martin Ceadel, "Popular Fiction and the Next War, 1918–1939," in *Class, Culture and Social Change,* ed. Frank Gloversmith (Sussex, 1980), pp. 161–84; and I. F. Clarke, *Voices Prophesying War, 1763–1984* (London, 1966).

eclipse provided irrefutable evidence of the deflection of light by the sun that Einstein had predicted, the result was an outpouring of press reports, scholarly articles, and popular books which cumulatively led to what Abraham Pais has termed the "canonization" of Einstein.[44] "Revolution in Science: New Theory of the Universe: Newtonian Ideas Overthrown" proclaimed the normally sedate *Times* on November 7, the day after the announcement of the observers' findings.[45] Other papers were quick to follow, as were more expert commentators. Indeed, the explanation of the general theory of relativity became the major intellectual preoccupation of British science writers in the early 1920s. Not merely was Einstein's own attempt at popularization quickly translated into English and the major reviews and newspapers deluged with articles, but a dizzying number of popular accounts also appeared, most influentially Eddington's *Space, Time, and Gravitation* (1920), Bertrand Russell's *The ABC of Relativity* (1925), James Jeans's *The Mysterious Universe* (1930), and Sullivan's *Three Men Discuss Relativity* (1926).[46] Such works served not simply to confirm Einstein's own achievement in the popular mind but also to begin to acquaint the general public with the radical reconstruction of classical physical theory proposed by the "suddenly famous Dr. Einstein."[47] Newtonian principles and commonsense assumptions died—and are still dying—hard, of course, and the intellectual limitations of even the most acute readers were quickly tested by the details of Einstein's doctrines. By 1930, however, something of Einstein's name, his genius, and his leading ideas would have been recognizable to a wide swath of the British reading public.

Similarly familiar in the 1920s—and with growing recognition every year of the 1930s—was the creation and development of nuclear, as opposed to atomic, physics. As with relativity theory, nuclear physics began before 1914 with the brilliant experiments of Rutherford in 1911 and pathbreaking papers by Niels Bohr in 1912–13.[48] It was only after

[44] Abraham Pais, *"Subtle is the Lord . . .": The Science and the Life of Albert Einstein* (Oxford, 1982), p. 305.

[45] *The Times* (November 7, 1919), p. 12. The findings of the expedition were announced at a joint meeting of the Royal Society and the Royal Astronomical Society on November 6.

[46] Albert Einstein, *Relativity: The Special and the General Theory,* trans. Robert W. Lawson (London, 1920); Arthur Eddington, *Space, Time, and Gravitation: An Outline of the General Relativity Theory* (Cambridge, 1920); Bertrand Russell, *The ABC of Relativity* (n. 5 above); James Jeans, *The Mysterious Universe* (Cambridge, 1930); J. W. N. Sullivan, *Three Men Discuss Relativity* (London, 1926).

[47] Quoted in Pais, *"Subtle is the Lord . . . ,"* p. 309.

[48] Excellent accounts of this work can be found in Keller (n. 4 above); and Pais, *Inward Bound* (n. 4 above).

the war, however, that those advances became widely known outside the scientific community, especially after they were dramatically extended by Rutherford's artificial disintegration of nitrogen atoms in 1919, the year of his return to Cambridge and the Cavendish. Beginning with Rutherford's own celebrated Bakerian Lecture to the Royal Society in 1920, British scientists and science writers worked incessantly to explain the ongoing research into nuclear structure. Scientists themselves took the lead, and the next decade saw the publication of dozens of magazine and newspaper articles as well as a number of outstanding introductions: a fourth and much-revised edition of Soddy's *The Interpretation of Radium* (1922), Andrade's *The Structure of the Atom* (1923) and *The Atom* (1927), N. R. Campbell's *The Structure of the Atom* (1923), Sullivan's *Atoms and Electrons* (1923), Lodge's *Atoms and Rays* (1924), J. A. Cranston's *The Structure of Matter* (1925), and George Thomson's *The Atom* (1930).[49] Such works, which emphasized the remarkable experimental findings of Rutherford, Aston, Charles T. R. Wilson, Blackett, and others, were careful, lucid, and of a uniformly high standard. Attentive readers, and there were enough such hardy souls to prompt reprintings and new editions of nearly all these books, would therefore have been extremely well informed about the continuing revolution in physics.

Equally informative and influential was the work of scientific popularizers and professional science writers, men such as Russell, Crowther, and Sullivan, who wrote not merely in the old reviews and magazines, but, increasingly, in the newly established popular science journals—such as *Discovery* and *Science Progress*—as well as in newspapers.[50] Crowther, the science correspondent of the *Manchester Guardian* and the first of that species in Britain, was especially acute and prolific. His scores of articles on contemporary physics—such as one on "Smashing the Atom" in April 1928—reached not only the many regular *Guardian* readers but—gathered into several extremely popular collections—a much broader audience as well.[51]

All such efforts at popularization were confessedly provisional; no British scientist or science writer, with the constant exception of

[49] Frederick Soddy, *The Interpretation of Radium,* 4th ed. (London, 1922); E. N. da C. Andrade, *The Structure of the Atom* (London, 1923), and *The Atom* (n. 5 above); N. R. Campbell, *The Structure of the Atom* (Cambridge, 1923); Sullivan, *Atoms and Electrons* (n. 5 above); Lodge, *Atoms and Rays* (n. 5 above); J. A. Cranston, *The Structure of Matter* (London, 1925); George Thomson, *The Atom* (London, 1930).

[50] *Discovery: A Monthly Popular Journal of Knowledge* was founded in January 1920 with the distinguished Oxford chemist A. S. Russell as its first editor.

[51] J. G. Crowther's collections include *Science for You* (London, 1929), *Short Stories in Science* (London, 1929), and *Osiris and the Atom* (London, 1932).

the irrepressible Soddy, was prepared to do more than indicate the direction of current research. In stark contrast with that provoked by the discovery of radioactivity as well as with that being produced in America and France, this literature was virtually free of specific speculations or vivid imaginings. One of the lessons which had plainly been learned in the intervening two decades was that any sort of practical application would be slow in coming and would do so only after an immense and protracted research effort in physics, chemistry, and engineering. Discussions of the potentialities of atomic energy in particular were therefore brief and punctilious. The physicist Andrade, for example, asserted in his popular survey *The Structure of The Atom* that since "the study of the structure of the atom is in its first youth . . . too much introspection is unhealthy."[52] Lodge was prepared to go slightly further and concede that "some of what we think of as atomic energy may be somehow made available," but he was quick to caution that it was "not yet tractable by any human device."[53] Similarly, Cranston, a physical chemist at the Royal Technical College, Glasgow, and a former student of Soddy's, confessed that although the release of atomic energy "would be far more valuable to mankind than the production of any element such as gold," the unavoidable fact remained that the current state of knowledge did not "give much encouragement to these views." In particular, Cranston observed accurately and uniquely, under present conditions a drastically larger "amount of energy would need to be *applied* in order to disrupt the nucleus" than would be released through that "disruption."[54] And even the normally optimistic Russell observed in his immensely successful *The ABC of Atoms* that the prospect of atomic energy remained "as yet in its infancy . . . no more than a speculative possibility."[55] All such commentators were prepared to recognize the existence of atomic energy and to concede at least the possibility of its eventual release and control; none were prepared to allow their imaginations to leap much beyond the confines of their laboratories.

The only exceptions to this caution—and they were both few and vague—concerned the possible creation of atomic weaponry. Given both his later career as a campaigner for nuclear disarmament and his earlier efforts as an opponent of Britain's involvement in the Great War, it is perhaps not surprising that Russell recognized—but only in a single line—that "it is probable that [atomic energy] will ultimately

[52] Andrade, *The Structure of the Atom,* p. 15.
[53] Lodge, *Atoms and Rays,* p. 197.
[54] Cranston, p. 183.
[55] Bertrand Russell, *The ABC of Atoms* (n. 5 above), p. 15.

be used for making more deadly explosives and projectiles than any yet invented.''[56] More surprisingly, the deeply conservative Lodge offered the hope that scientific progress would not outstrip moral and political advance and create weapons which could be used ''for deleterious and deadly purposes.''[57]

British novelists and playwrights, by contrast, were neither as inhibited nor as scrupulous as their scientific contemporaries, and the 1920s saw the publication of several works in which atomic energy was indeed put to the lethal purposes Lodge deplored. J. J. Connington's *Nordenholt's Million* (1923), for example, featured an atomic catastrophe sparked off by a physicist attempting to harness atomic energy through ''induced radioactivity'' but producing instead only a ''high detonation'' and the obliteration of his own laboratory.[58] His successors, by contrast, were able—using his notes and after a series of ''fearful explosions''—to ''tap the stores'' of atomic energy and create ''atomic engines'' which ran tirelessly, cheaply, and, reminiscent of Wells, ''made the employment of human labour supererogatory.''[59] Since, however, a bacteriological infestation had wiped out nearly all the world's population, mass unemployment proved not to be a problem. Instead, the survivors—concentrated improbably in the Glaswegian hinterlands—enjoyed lives of prosperity, idleness, and boredom.[60] A similar use of the ''inexhaustible source of power'' within the atom appeared briefly in Olaf Stapledon's remarkable science fiction novel, *Last and First Men* (1930), a sprawling and often incoherent account of ''two thousand million years'' of human history.[61] First mastered by an obscure Chinese physicist in the early 1930s, atomic energy proved to be so ''easily manipulated and controlled'' that it soon found its way into ordnance production. At a meeting of international scientists at Plymouth, a demonstration of a small atomic device intended to set off a carefully delimited process of atomic disintegration proved at once unexpectedly destructive and eerily prescient:

> For a dazzling point of light appeared on the remote cliff. It increased in size and brilliance, till all eyes were blinded in the effort to continue watching. It lit up the under parts of the clouds and blotted out the

[56] Ibid., p. 11.
[57] Lodge, *Atoms and Rays*, p. 201.
[58] J. J. Connington, *Nordenholt's Million* (London, 1923), pp. 237, 263. ''Connington'' was the pseudonym of A. W. Stewart, professor of chemistry at Belfast.
[59] Ibid., pp. 273–75, 283.
[60] *Nordenholt's Million* was reissued as a Penguin paperback in 1946.
[61] Olaf Stapledon, *Last and First Men* (1930); reprint, Los Angeles, 1988), pp. 96, 169.

> sun-cast shadows of gorse bushes besides the spectators. The whole end of the island facing the mainland was now an intolerable scorching sun. Presently, however, its fury was veiled in clouds of steam from the boiling sea. Then suddenly the whole island, three miles of solid granite, leapt asunder; so that a covey of great rocks soared heavenward, and beneath them swelled more slowly a gigantic mushroom of steam and debris. Then the sound arrived. All hands were clapped to ears, while eyes still strained to watch the bay, pocked white with the hail of rocks.[62]

The mushroom cloud was born.

Less prophetic but far more comprehensible and popular was *Wings over Europe,* a play by the British poets and playwrights Robert Nichols and Maurice Browne and first performed in New York in 1928 and London in 1930. Set entirely in the Cabinet Room at 10 Downing Street, the play revolves around the announcement by a brilliant young British physicist, Francis Lightfoot, that he has discovered the secret of releasing and controlling atomic energy. Stereotypically "highly strung," "reclusive," and bearing a perpetual "unearthly" expression, Lightfoot—who happens contrivedly to be the Prime Minister's nephew—explains to a befuddled Cabinet that in the course of research at his isolated laboratory in North Wales he has perfected a technique capable of controlling "atomic redistribution": "Gentlemen, I can control . . . the energy . . . in the atom."[63] The ministers—caricatures of two centuries of Tory politicians—prove uncomprehending, except for the monocle-sporting, Croce-reading Evelyn Arthur, the Foreign Secretary and every inch a bad parody of Arthur Balfour. When Lightfoot explains that "Man's Free," that there is now dawning "the New World, the Summer of Mankind, the Golden Age," and that Man, now "a Titan, a Prometheus, a Prometheus Triumphant, [can devote] all his days and nights [to] one long hymn of praise to Beauty and to Truth," he is aghast to discover that his audience is utterly ignorant and unappreciative of his findings.[64] To his dismay, only the Secretary for War grasps the full consequences of his discovery and crows that henceforth Britain will be "cock o' the walk an' teach all other peoples on the globe where they get off."[65] In order to confirm the authenticity of his discovery and to threaten the ministers with extinction should they not begin immediately to revolu-

[62] Ibid., p. 28.

[63] Robert Nichols and Maurice Browne, *Wings over Europe* (New York, 1928), pp. 5, 10, 28, 41, 49.

[64] Ibid., pp. 51–52.

[65] Ibid., p. 97.

tionize government, society, and the economy to take account of atomic energy, Lightfoot then offers a week's delay and a demonstration—not of his ability to turn the Cabinet table into gold, which is suggested, but of his capacity to detonate a weapon of unprecedented mass destruction. Witnessed by the entire Cabinet offstage, Lightfoot blows a hole "as big as St. Paul's" somewhere in the West Country. In response to this striking evidence, the Cabinet chooses not to agree to the principles of disarmament and social reorganization that Lightfoot insists on, but instead to kidnap and arrest him. Escaping the clutches of a pistol-waving Secretary for War, Lightfoot—armed with the detonator of another atomic device hidden somewhere in central London—offers the ministers a final chance at salvation and sets off for a walk in St. James's Park while they mull over his ultimatum. The situation is only saved—and preposterously at that—when Lightfoot is struck by a lorry and killed, taking his secret with him, on his return from St. James's.

As such a summary makes plain, *Wings over Europe* is not one of the century's great dramas. Full of pious speeches, peopled by ludicrously overdrawn characters, and appallingly contrived, the play nonetheless received critical acclaim in New York and London and was often revived—especially by student groups—throughout the 1930s.[66] And although its appreciation of nuclear physics was deeply inaccurate—the bomb responsible for the massive crater in the West was allegedly the result of the rearrangement of the atoms in a lump of sugar—the play succeeded in alerting its many viewers to the possibilities of atomic destruction, in reinforcing their cultural stereotypes about the place and character of science and scientists in contemporary society, and—as will be seen—in prompting a new genre of political—as distinct from science fiction or next-war—tales with a nuclear theme.

Incomparably more important in inspiring fictional interest in atomic energy and weapons, however, was both the astonishing advance of basic physical research in the 1930s and the growing prospect of war with every year of that unhappy decade. The 1930s were, of course, a time of spectacular achievement in all areas of nuclear physics; indeed, scarcely a year passed without at least one major development: 1930 witnessed the prototype of Lawrence's cyclotron; 1932 the discovery of the neutron, positron, and deuterium as well as the "splitting" of a lithium target by accelerated protons; 1934 the induce-

[66] Maurice Browne, *Too Late to Lament* (Bloomington, Ind., 1966), p. 299.

ment of artificial radioactivity by the Joliot-Curies and the effort by Enrico Fermi to produce such artificial radioactivity through nearly all the periodic table; 1935 the discovery of the first transuranic elements; 1936 the formulation of Bohr's liquid-drop model of the atom; 1938 the detection of fission by Otto Hahn and Felix Strassmann. No wonder that the normally reticent Cockcroft recalled that he and his colleagues at the Cavendish "were living in the Golden Age of physics, so rapidly did discoveries come along."[67]

These discoveries were followed with growing attention in Britain, and British scientists and science writers continued their efforts at explication. New editions of earlier surveys were commissioned, such as Jeans's *The Mysterious Universe* (1932), Andrade's *The Atom* (1936), and Soddy's *The Interpretation of the Atom* (1932), and additional texts written, such as G. C. Darwin's *The New Conceptions of Matter* (1931), Jeans's *The New Background of Science* (1933), and G. K. T. Conn's *The Nature of the Atom* (1939).[68] Articles in the traditional reviews, weekly press, newspapers, and popular science magazines also appeared in growing numbers. As had been the case with its predecessors in the 1910s and 1920s, such literature was of a remarkably high standard. Science journalists such as Crowther and Sullivan were especially prolific and took great care to explain the astonishing advances with precision and speed.[69] Similarly, British scientists continued to speak to a broad audience in lectures, interviews, popular essays, and the like. Rutherford's *The Newer Alchemy* (1937), Aston's "Forty Years of Atomic Theory" (1936), and Norman Feather's "1932—and After: The New Physics of the Nucleus" (1934) were representative texts.[70]

What is most striking about this abundant literature—and what distinguishes it most sharply from comparable American and French writing on nuclear energy—is not its lucidity and intelligence but its reticence, its refusal to speculate about the possible applications of

[67] Quoted in Alwyn McKay, *The Making of the Atomic Age* (Oxford, 1984), p. 17.

[68] James Jeans, *The Mysterious Universe,* 2d ed. (Cambridge, 1932); E. N. da C. Andrade, *The Atom,* 2d ed. (London, 1936); Frederick Soddy, *The Interpretation of the Atom* (London, 1932); G. C. Darwin, *The New Conceptions of Matter* (London, 1931); Conn (n. 5 above).

[69] See, e.g., J. G. Crowther, "New Particles," *Nineteenth Century* 115 (February 1934): 208–19, "The Neutron," *Nineteenth Century* 111 (May 1932): 590–602, and "Breaking Up the Atom," *Nineteenth Century* 112 (July 1932): 81–94; J. W. N. Sullivan, "Secrets of the Atom," *Fortnightly Review* 146 (June 1936): 713–20.

[70] Ernest Rutherford, *The Newer Alchemy* (Cambridge, 1937); F. W. Aston, "Forty Years of Atomic Theory," in *Background to Modern Science,* ed. Joseph Needham and Walter Pagel (Cambridge, 1938), pp. 93–114; Norman Feather, "1932—and After: The New Physics of the Nucleus," *Science Progress* 29 (October 1934): 193–209.

current research. Neither the earlier extravagant claims of Soddy and Wells nor even the more modest assertions of Lodge and Russell were followed up in the light of recent research. The most famous British scientist of the decade, Ernest Rutherford, was notoriously loath to speculate and missed few opportunities to douse even the faintest of embers of conjecture. At the 1933 meeting of the British Association for the Advancement of Science, for example, Rutherford offered what became an oft-repeated dismissal: "Any one who says that with the means at present at our disposal and with our present knowledge we can utilize atomic energy is talking moonshine."[71] Three years later, in the prestigious Sidgwick Lecture at Cambridge given only months before his death, Rutherford pronounced that "the outlook for gaining useful energy from the atom by artificial processes of transformation does not look promising" and asserted bluntly that those—chiefly, although not exclusively, in America—who hoped that particle acceleration might offer a useful technique were mistaken: "There is little hope of gaining useful energy from the atoms by such a process."[72] Similarly, the other great heavyweight of Cambridge science, the brilliant astrophysicist Eddington, declared in 1935 that the practical application of nuclear energy was "no more than a dream for idle moments."[73] But perhaps the most eloquent testimony to the reluctance of British scientists even to meditate on the possibility of the peaceful use of nuclear energy came from Soddy himself, then Dr. Lee's Professor of Chemistry at Oxford. In his splendid *The Interpretation of the Atom,* published late in 1932 was a "replacement" for his long out-of-print *The Interpretation of Radium,* Soddy offered an austerely elegant exposition of a very high quality, with superb chapters on atomic structure, quantum theory, isotopes, and the like. But of the old passages foretelling a smiling Garden of Eden, there was not a single word.[74]

What little speculation there was in Britain about possible applications of nuclear energy was uniformly pessimistic and focused on what most contemporaries judged—and with growing anxiety with every passing year—to be the most pressing concern of the day: the coming war. Eddington, for example, worried in his popular *New Pathways*

[71] Ernest Rutherford, "Atomic Transmutation," *Nature* 132 (September 16, 1933): 432–33.

[72] Ernest Rutherford, *Newer Alchemy,* p. 65.

[73] Arthur Eddington, *New Pathways in Science* (Cambridge, 1935), p. 163.

[74] Soddy, *The Interpretation of Radium* (n. 19 above). Nor did Soddy's self-professed atomic disciple, H. G. Wells, ever return to the theme of nuclear energy or atomic warfare in any of his dozens of books or scores of articles written after 1914, not even in *The Shape of Things to Come* (London, 1933)—a widely read novel turned into a popular film three years later.

in Science (1935) that although nuclear energy was a "dream," its unlikely mastery would mean most immediately "unlimited power for war and destruction," a prospect he confessed to be "ominous."[75] Another of Rutherford's Cambridge colleagues, the distinguished physicist and Nobel laureate Aston, echoed Eddington's concern in a Cambridge lecture in 1936. "We can only hope," Aston judged of mankind's attempt to harness atomic energy, "that he will not use it exclusively in blowing up his next door neightbor."[76] Nor was the Oxford psychologist William McDougall any more sanguine: "And if some physicist were to realize the brightest dream of his kind and teach us to unlock the energy within the atom, the whole race of man would live under the threat of sudden destruction."[77] Even the usually ebullient J. B. S. Haldane, to offer a final example, repeated throughout the 1930s a warning he had first issued in 1924: "If we could utilize the forces which we now know to exist inside the atom, we should have such capacities for destruction that I do not know of any agency other than divine intervention which would save humanity from complete and peremptory annihilation."[78]

One of the most remarkable features of this virtually unanimous refusal of British scientists and popular science writers to seize on any but the possibly disastrous applications of nuclear energy is how different their attitude was from that of their American colleagues. In the United States, as Lawrence Badash, Martha Bartlett, and Spencer Weart have made plain, the interwar years saw a growing popular enthusiasm for nuclear energy, an excitement fueled by scientists themselves as well as by journalists, popular science writers, and science fiction authors.[79] At nearly the same moment Rutherford was dismissing atomic energy as so much "moonshine," for example, Lawrence was boasting that his cyclotron had "opened the atom for business," and Robert Millikan was predicting "a new world for man."[80] And while Britain's most eminent science journalist, Crowther, was concluding lamely that Cockcroft and Ernest Walton's "splitting" of

[75] Eddington, *New Pathways,* p. 163.

[76] Aston, p. 114.

[77] William McDougall, *World Chaos: The Responsibility of Science* (London, 1931), p. 45.

[78] J. B. S. Haldane, *Callinicus: A Defence of Chemical Warfare* (London, 1925), p. 15.

[79] Lawrence Badash, *Nuclear Fission: Reaction to the Discovery in 1939* (San Diego, Calif., 1985); Martha A. Bartlett, *The Way to Ground Zero: The Atomic Bomb in American Science Fiction* (New York, 1988); Weart (n. 2 above), pp. 55–101.

[80] Lawrence quoted in Daniel J. Kevles, "Begetting Big Science," *New York Review of Books* (October 25, 1990), p. 8; Millikan, quoted in Weart, p. 33.

lithium atoms "must result in greater control over Nature," the chief science correspondent of the *New York Times,* Waldemar Kaempffert, was promising that the imminent harnessing of nuclear energy would lead to "thousands of small towns with plenty of garden space, low rents, breathing space . . . health, and a finer outlook on life."[81]

America was home as well in the 1920s and 1930s to a remarkably rich genre of literature of scientific prediction. Written almost exclusively by scientists themselves, these works were relentlessly optimistic, exquisitely detailed, and widely read. The Yale engineer C. C. Furnas, for example, predicted in his *The Next Hundred Years* (1936) that the ongoing discoveries in physics guaranteed "energy for the taking," and the MIT chemist George Russell Harrison included lengthy chapters such as "When Physics Goes Farming" in his *Atoms in Action* (1939), as did the physicist Rogers Rusk—"Hunting for Big Game among the Atoms"—in his *Atoms, Men, and the Stars* (1937).[82] In Britain, by contrast, there were scarcely any such books, and those that appeared, such as Haldane's *Daedalus, or Science and the Future* (1923) and Russell's *Icarus, or the Future of Science* (1925), were at once extremely short, deeply pessimistic, and scarcely willing to discuss any aspect of current research in the physical sciences. Haldane's work, for example, predicted that thousands of windmills would provide all energy needs in the future.[83] Tellingly, when the Scientific Book Club commissioned a full-scale survey of *Frontiers of Science* in 1937, they appealed to an American, the physicist Carl Trueblood Chase, to write it.[84]

Interwar America, moreover, was also the scene of an astonishing craze in science fiction literature and films which also had virtually no British counterpart. To be sure, some devoted British filmgoers worried whether Flash and Dale would escape the clutches of Ming the Merciless, and British audiences lined up to see such immensely popular American "next-war" films as *Murder in the Air* (1938), in which an American Secret Service agent—preposterously named Brass Bancroft—secures a new "superweapon," a defensive beam designed "to

[81] Crowther, "Breaking Up the Atom" (n. 69 above), p. 81; Kaempffert, quoted in Weart, pp. 11–12.

[82] C. C. Furnas, *The Next Hundred Years* (New York, 1936), p. 188; George Russell Harrison, "When Physics Goes Farming," in his *Atoms in Action* (London, 1939); Rogers Rusk, "Hunting for Big Game among the Atoms," in his *Atoms, Men, and the Stars* (London, 1937).

[83] J. B. S. Haldane, *Daedalus, or Science and the Future* (London, 1923), pp. 24–25, Bertrand Russell, *Icarus, or the Future of Science* (London, 1924).

[84] Carl Trueblood Chase, *Frontiers of Science* (London, 1937).

make America invincible" by shooting down enemy bombers.[85] But the rich profusion of science fiction films, many of which featured prominently various nuclear devices ranging from atomic-powered cars to radium watches to uranium explosives, that spread over America were virtually unwatched by British audiences and were certainly not imitated by British filmmakers. Nor did the boom in science fiction literature—from the pulps to the respectable—cross the Atlantic and expose British readers to the nuclear imaginings that filled *Amazing Stories, Science Wonder Stories,* and *Astounding Science Fiction.* As the most astute Brtitish student of this literature has concluded, science fiction writing of every sort was "insignificant in the British literary marketplace before 1945," and "pulp publishers never showed any interest in Britain as a market."[86]

What Britain did produce in the 1930s, by contrast, was the occasional novel with a nuclear motif, usually quite well into the background. Harold Nicolson's *Public Faces* (1932), to give the most prominent example, was a popular novel of political satire and diplomatic manners with such a nuclear theme. Set in 1939, the novel opens with the Liberal Party, implausibly, in office. The Cabinet is faced with a diplomatic crisis in the Middle East provoked by British acquisition of a monopoly of a rare ore, found exclusively on an island off Persia, from which can be refined one metal essential to the production of rocket planes and another to the building of atomic bombs. The Foreign Secretary convinces a wavering Cabinet that "it would be impious for us to dabble in the Satanic possibilities of the atomic bomb." But, aware that the Conservative opposition would look upon such a bomb approvingly as a "weapon of world dominion" yet frightened by the catastrophic potential of their secret, the Cabinet vacillates over whether to begin production.[87] To steal a march on the bellicose Tories, the Secretary for Air secretly authorizes a nuclear test. Expecting that such a test would result in the destruction of "an area of thirty almost desert miles," the Air Ministry is stunned to learn that the explosion, detonated in the Atlantic rather than over land, is far greater than anticipated, "destroying all matter within a circumference of seventy to eighty miles from the point of explosion." Not merely does the blast create "a thick black cloud whirling westwards with the speed of a hurricane," but a gigantic tidal wave sinks an American warship and "overwhelms" Charleston, South Carolina, killing tens of thou-

[85] The star of *Murder in the Air*? Who else but Ronald Reagan.

[86] Brian Stableford, *Scientific Romance in Britain, 1890–1950* (New York, 1985), pp. 151, 371. There is a comparable American study in Bartlett.

[87] Harold Nicolson, *Public Faces* (London, 1932), p. 157.

sands of "innocents."[88] The war that threatens to engulf the world as a result is prevented only when the British government—through the agency of an idealistic young Foreign Office minion who exceeds his authority by secretly rewriting the official communiqué—pledges to destroy all its atomic weapons and to manufacture none in the future. This startling initiative, done utterly in defiance of the Foreign Office mandarins and Cabinet members Nicolson mocks so pitilessly, leads almost immediately to world disarmament and peace.

Lewis Grassic Gibbon's *Gay Hunter* (1934) and J. B. Priestley's *The Doomsday Men* (1938) were two other popular novels which featured nuclear elements. In *Gay Hunter* the eponymous heroine, an American debutante visiting Britain on holiday, dreams herself forward 20,000 years into a postapocalyptic world which has been ruined by atomic warfare and "the poisoning dust that comes from the atomic bombing."[89] A mixture of science fiction tale and romance novel, the book found a wide and responsive readership mesmerized by Gibbon's haunting account of the "reversion" of the survivors of a nuclear holocaust to a state of moral and social primitivism. Similarly popular was Priestley's *The Doomsday Men,* an often hilarious adventure yarn and social commentary which features a megalomaniacal American scientist who retreats deep into a secret installation in the desert of the American Southwest—Mojave, in this instance, not Alamogordo—where he prepares to set off an atomic reaction that "would peel the skin off the earth like an orange, only faster" and is frustrated in his aims by a drunkard in a biplane who crashes into the site.[90] Such novels, importantly, were only incidentally concerned with nuclear energy; most, instead, were either love stories, adventure tales, political satires, or future-war fables, and were thus more interested in social criticism and more expressive of cultural anxiety than they were predictive of atomic utopias. Indeed, in striking contrast with simultaneous American works but in close harmony with contemporary British writing on popular science, science fiction, and history of science, none was about any imagined benevolent uses of atomic energy. Rather, all presented atomic energy exclusively as a threat, as the source, indeed, of potentially the most destructive weapon in human history.

II

On the morning of September 1, 1939, the preeminent British popular science magazine, *Discovery*, published as its leading article a

[88] Ibid., pp. 303, 325.
[89] J. Leslie Mitchell [Lewis Grassic Gibbon], *Gay Hunter* (London, 1934), p. 86.
[90] J. B. Priestley, *The Doomsday Men* (New York, 1938), p. 255.

provocative essay by its editor, C. P. Snow. Entitled ominously "A New Means of Destruction?" it informed its nervous readers that the "atomic age" was about to open: "Some physicists think that, within a few months, science will have produced for military use an explosive a million times more violent than dynamite." Worse even than the imminence of such a weapon, Snow continued, was its certainty: "It is no secret; laboratories in the United States, Germany, France and England have been working on it since the Spring," and opinion at the Cavendish, he reported, "think it as good as done."[91] Indeed, "if it is not made in America this year," Snow predicted chillingly, "it may be next year in Germany." Happily, he asserted, American scientists had been quick off the mark and had acquired a "six months' start": "In America, as soon as the possibility came to light, it seemed so urgent that a representative of American physicists telephoned the White House and arranged an interview with the President. . . . It is in America where the thing will be done."[92] The Manhattan Project had begun.

Attentive readers of *Discovery* as well as careful students of the British popular press would have understood the experimental provenance of Snow's article, as well as that of a more technical companion piece written by Douglas W. F. Mayer on "Energy from Matter."[93] In the ten months since the discovery of nuclear fission by Hahn and Strassmann in December 1938 and the publication in January and February 1939 of Otto Frisch and Lise Meitner's celebrated papers, over one hundred papers on fission had been published in the technical journals, as well as dozens more in newspapers and magazines.[94] The possibility of an atomic bomb—for so long a distant subject of doomsday speculation—and the chance of a major European-wide war—for so long a dreaded consequence of political failure—had come together in a fateful conjuncture.

Literally on the eve of the Second World War the vague dreams of atomic beneficence that had begun the century had been replaced by realistic nightmares of nuclear annihilation. As is well known, with the outbreak of war public discussion of atomic energy or nuclear weaponry virtually ended in Britain as "official" activity accelerated.[95]

[91] C. P. Snow, "A New Means of Destruction?" *Discovery*, n.s., 2 (September 1939): 443.

[92] Ibid., p. 444.

[93] Douglas W. F. Mayer, "Energy from Matter," *Discovery*, n.s., 2 (September 1939): 459–60.

[94] McKay (n. 67 above), p. 35; Badash, *Nuclear Fission* (n. 79 above), pp. 1–41.

[95] The best study of that "official" activity is Gowing, *Britain and Atomic Energy* (n. 3 above). Also well worth examining is Richard Rhodes, *The Making of the Atomic Bomb* (Harmondsworth, 1988).

Britain thus entered (and left) the war with the same nascent, deeply pessimistic nuclear culture it had evolved since the late nineteenth century. In Britain, as has been seen, no science fiction enthusiast, filmmaker, novelist, journalist, or politician had offered even a glimmer of an atomic utopia for nearly a generation. Nor, and again in direct contrast with America, had any British scientist proclaimed even the possibility of such a nuclear paradise. Indeed, for nearly all of the 1930s British scientists had vied with one another in their efforts to squelch any expressions of enthusiasm for possible applications of atomic energy. This reluctance, so strikingly absent in the United States, was in some measure idiosyncratic to the individual scientists themselves. Ernest Rutherford, for example, was notoriously unwilling to conjecture publicly (or even privately) about the practical utility of any of his research and was equally legendary in his majestic disapproval of those scientists who ventured to do so; only a rare soul as brave, reckless, and freethinking as Soddy dared to chance Rutherford's forbidding disapprobation. Eddington, to offer a second example, was far more willing to engage in modest speculation about the practical implications of contemporary scientific research, but in the case of atomic physics, Eddington's devout pacifism made him very loath to tolerate even the faintest conjecture about atomic energy. And Soddy, to identify the likeliest suspect, had by the mid-1930s improbably turned his attention to questions of economic theory and currency reform, subjects on which he wrote prolifically and bored unremittingly. No important British scientist, that is, offered either the informed speculation of the fanciful guesswork about the potentialities of atomic energy that would have fed the popular imagination or satisfied journalistic ravenings. Nor did any British scientist break the link. first forged by Soddy at the turn of the century, between the mastery of atomic power and the unleashing of nuclear weaponry; in Britain, unlike America, the two developments were never seen in isolation.

There was, to be sure, more than simply a difference in temperament that separated British scientists from their American counterparts. Considerations of funding almost certainly also played a role in the evolution of their very different attitudes toward scientific research generally and atomic energy specifically. In Britain, broadly speaking, science was done on the cheap. Reminiscences about the research conditions even at the relatively flush Cavendish are uniform in their descriptions of the cheese-paring practices then prevalent, practices sanctioned by Rutherford's own strongly held conviction that technology must not be permitted to take the place of hard thought. Tellingly, both Mark Oliphant and John Cockcroft, two of Rutherford's most admired and trusted acolytes, had to leave the Cavendish in order to build the accelerators necessary to their researches. In America, by contrast, the funding for much contemporary physics came from industry, philanthropists, and foundations; it was not the University of California but utilities, pharmaceutical companies, and the Rockefeller Foundation, to offer but one prominent example, which largely financed successive versions of Lawrence's cyclotrons—to say nothing of Millikan's efforts to endow the California Institute of Technology. Such highly visible, avowedly entrepreneurial scientists—ever willing to give interviews, conduct tours, offer demonstrations, and engage in speculations which journalists could adopt and exaggerate as their own—had virtually no British equivalents. British and American scientific cultures, a subject about which we need to know a great deal more, were remarkably distinct.[96]

Nor did the abiding moral, political, and cultural pessimism which so pervaded interwar Britain find many echoes in America. Anxieties over the increasingly intimate relations between science, technology, and weaponry—concerns born in the First World War—became ever more acute in Britain with the construction of bomber squadrons, the expansionism of dictators, and the realization of the potential risk to civilians posed by the apparently unavoidable war. It was, after all, a British prime minister and not an American president who warned about bombers always getting through and an British bishop (of Ripon), not an American clergyman, who proposed a suspension of scientific research to allow humankind's moral progress to catch up to its technological attainments.

Nor did Britain see much momentum generated during the war for the peaceful use of atomic energy. The unambiguous prewar imagery of nuclear paradise that would help to sustain popular support for the Atomic Energy Commission in America in the years after the war was absent from Britain. In its place was a nascent nuclear culture, itself the slow accumulation of half a century of imagery and knowledge, which had at its heart the imagery of destruction—confirmed by Hiroshima and Nagasaki—and which would lead not to dreams of nuclear millennium but to the Campaign for Nuclear Disarmament.

[96] There is, alas, no study of science funding in Britain. Some indication of American practices can be found in J. L. Heilbron and Rovert W. Seidel, *Lawrence and His Laboratory: A History of the Lawrence Berkeley Laboratory* (Berkeley, 1989); Robert H. Kargon, *The Rise of Robert Millikan* (Ithaca, N.Y., 1982); Daniel J. Kevles, *The Physicists: The History of a Scientific Community in Modern America* (New York, 1978).